Multivariate analysis of osteometric traits in Italian moles (genus *Talpa*)

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Abstract

A morphometric study was performed on skeletal components (mandible) to elucidate the taxonomical interrelationships between the Italian moles (genus *Talpa*), mainly to ascertain the specific status of *Talpa romana* Thomas. 163 specimens of *T. romana, T. europaea* and *T. caeca* were submitted to a multivariate analysis of 15 characters. The results indicate that the three taxa are well discriminated by very high eigenvalues of Discriminant Functions (DF I = 8.92425; DF II = 3.12768). The Wagner network shows a greater distance between *T. romana* and *T. europaea* than between the latter and *T. caeca.* The three taxa can be considered as different species on phenetic criteria.

Introduction

The taxonomy and the phyletic relationships of Italian moles (genus *Talpa*) still represent a controversial problem. It is believed that three different taxa exist in the Italian geographic area, i. e. *Talpa europaea* L., *T. romana* Thomas and *T. caeca* Savi. In particular the specific status of *T. europaea* and *T. romana* have not yet found a definite solution. Toschi (1959), Stein (1960) and Schwartz (1958) proposed to regard *europaea* and *romana* as different species, whereas Ellerman and Morrison-Scott (1951) and more recently Saint Girons (1973) considered *romana* a subspecies of *europaea.* Till now these taxa were considered to occupy allopatric areas: *Talpa europaea* occupies North and Central Italy, whereas *T. romana* is distributed in the central and Southern part of the country. However, no extensive samplings were made to single out possible sympatric overlaps between the distribution areas of the two taxa.

Karyological analyses carried out by Meylan (1966), Gropp (1969) and Capanna (1981) showed no difference in the karyotype patterns (diploid number 34) of *T. romana* and *T. europaea;* on the contrary, as far as *Talpa caeca* is concerned, the difference in its karyotype (diploid number 36) and its sympatric coexistence both with *T. europaea* and *T. romana* strengthen its specific status.

An attempt to discriminate these two taxa, i. e. *Talpa europaea* and *T. romana,* through a morphological approach, was carried out by Petrov (1971) on the Macedonian morphae of these taxa and, more recently, by Capanna (1981) who re-examined from the cytological and morphological point of view the topotypic population of *Talpa romana.* Both authors stressed the relevance of certain cranial and dental features in order to characterize each taxon. Undoubtedly a multivariate approach to this problem would offer an extremely sensitive instrument to evidence differences in size and shape of skeletal structures. In fact the great advantage offered by multivariate analysis mainly stands in considering simultaneusly a large numbers of characters which, if regarded singly, might not be informative.

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Table

Numbers of animals and source of the material

Species	Localities	Numbers of animals ♂	♀	Total	Institutions	Collection code
Talpa romana	Ostia (Latium)	13	13	26	Dept. Animal Biol., Roma	Acr 1–26
	Roccarainola (Campania)	14	4	18	Museo Zoologico, Firenze	8168–8179; 6101; 6107–6109; 6118–6119.
Talpa europaea	Ravenna (Emilia-Romagna)	26	2	28	Museo Zoologico, Firenze	7725–7726; 8612–8637:
	Leinì (Piedmont)	20	17	37	Museo Storia Nat., Verona	690–693; 1041–1052: 1058; 1073–1073; 1108–1109; 1393; 1632–1634; 1849–1850: 2452–2461.
Talpa caeca	Gressoney (Valle d'Aosta)	21	23	44	Museo Zoologico, Firenze	6959–6968; 7411–7444.
	Val di Lanzo (Piedmont)	5	0	5	Museo Storia Nat., Verona	454; 660–662; 1310.
	Aquila (Abruzzo)	5	0	5	Museo Storia Nat., Verona	2151–2152; 2275; 2298; 2502.

As previous experiences of multivariate morphometric analysis both on laboratory strains (Festing 1972, 1973, 1976; Leamy 1975) and on wild populations of *Mus musculus domesticus* (Thorpe et al. 1982) and of *Sorex* (Hausser and Jammot 1974) demonstrated that the mandible represents a pool of highly inheritable characters, this bone was used in this research too as source of data.

Material and methods

163 animals were examined coming from the collections of the "Museo Zoologico della Specola" of the University of Florence, and of the "Museo Civico di Storia Naturale" of Verona and of the Department of Animal and Human Biology of the University of Rome (see Table).

The three taxa are represented by: i- *Talpa romana,* 26 specimens from terra typica (Ostia, Latium), 18 specimens from Southern Italy (Roccarainola, near Naples, Campania); ii- *Talpa europaea,* 28 specimens from Ravenna (Emilia-Romagna), 37 specimens from Leinì (near Turin, Piedmont); iii- *Talpa caeca,* 44 specimens from Gressoney (Val d'Aosta), 5 specimens from Val di Lanzo (near Turin, Piedmont), 5 specimens from l'Aquila (Abruce).

On each left mandible 15 measures were taken (Fig. 1) after placing the bone on a photographic negative of mm-graph paper reduced 9 times, accordingly to a quick method elaborated by Festing (1972) and modified by Thorpe et al. (1982). The mandible was kept in place by two fixed glass slides, and observed through a binocular microscope. As all the individuals belong to the same age class (adults), it was not necessary to eliminate the influence of allometric growth as Thorpe et al. (1982) did.

The main purpose of this study was not only to display morphometric divergence and relative similarity among taxa, but also to find a methodology which could set up assignement or identification rules for further specimens whose taxonomical position is unknown. Principal Component Analysis (PCA) and Discriminant Function Analysis (DFA) are the multivariate statistical procedures especially appropriate for these purposes. PCA allows to order the individuals in the space and can single out separate groups that cannot a-priori be determined; DFA maximizes the amount of variation among groups relative to that within groups. Nevertheless this statistic procedure re-

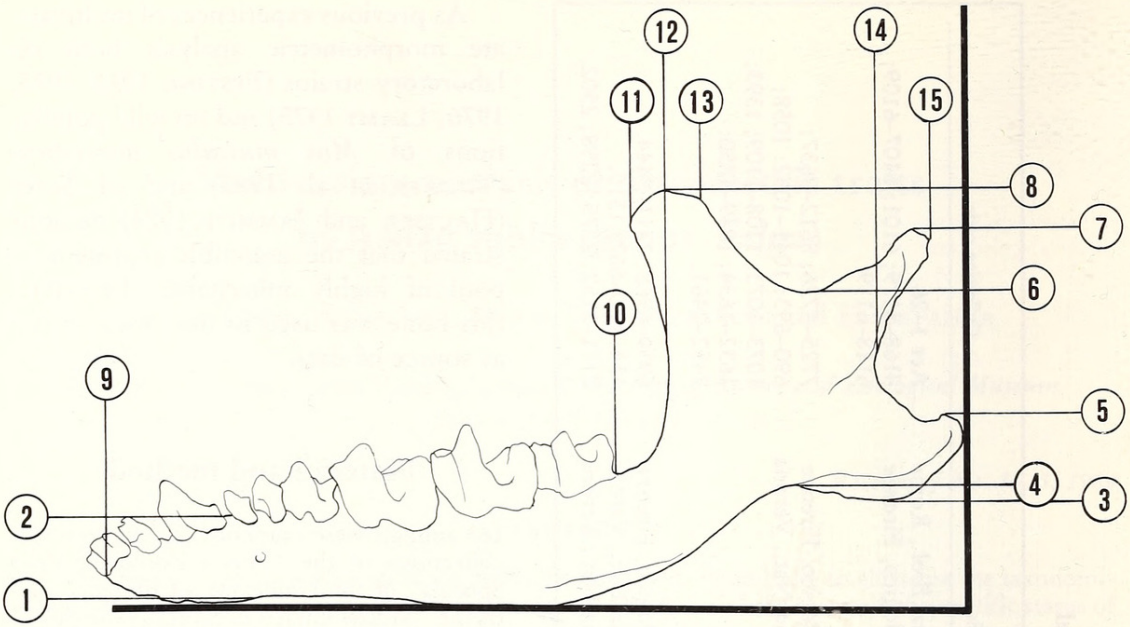

Fig. 1. Recorded characters for the left mandible. The bone is placed on photographic negative of mm-graph paper reduced 9 times and observed through a binocular microscope. The constant position is obtained by laying the mandible against two fixed glass slides

quires: i- a-priori defined groups and ii- respect of the assumption of multivariate normality and homogeneus variance-covariance among groups. Consequently, each DFA was carried out using, as new data, the component scores from previously computed PCA. According to this procedure it is impossible to go back again to the discriminant power of single characters or combination of characters: this objective was infact trivial to the aim of this study.

P4M and P7M programs (BMDP 79, Biomedical Computer Programs, Health Science Computing Facility, University of California, L. A.) were used for multivariate analyses carried out on a Sperry Univac EXEC 1100 computer (Centro di Calcolo Interfacoltà, University of Rome).

Results and discussion

Since the first main question concerns the morphometric distinction between *Talpa romana* and *Talpa europaea*, the analysis was carried out considering the *europaea/romana* Operational Taxonomic Units (OTUs) on the basis of their geographic locality (Fig. 2).

PCA performed pooling the two sexes does not identify a clear separation between taxa; whereas PCA computed on each sex separately allows to distinguish well separated groups. Sexual dimorphism affects seriously the pattern of distribution of specimens in the multidimensional space, on the contrary of what was indicated in other studies (Hausser and Jammot 1974). Moreover it is important to isolate sexual dimorphism from other components of intraspecific non-geographic variation (Thorpe 1976).

The component scores computed on each sex separately were used as new data matrix for DFA. Discriminant Functions (DF) clearly distinguish two different categorical clusters, one for the *T. romana* populations and another for the *T. europaea* ones, as indicated by the high eigenvalues of the first two DFs (DF I = 5.30836; DF II = 0.64022), the canonical correlation is 0.91732 and 0.62476 respectively. A cline of morphometric variation according to the geographic distribution of the taxa is not recognizable (Fig. 2); this pattern of categorical cluster rules out the possibility that the two taxa may be considered separated at a subspecific level. On the other hand, the relative similarity among OTUs, computed from a matrix of Manhattan distances between population means are large enough to consider *Talpa europaea* and *Talpa romana* as belonging do different phenetic species (sensu Sneath and Sokal 1973) (Fig. 2).

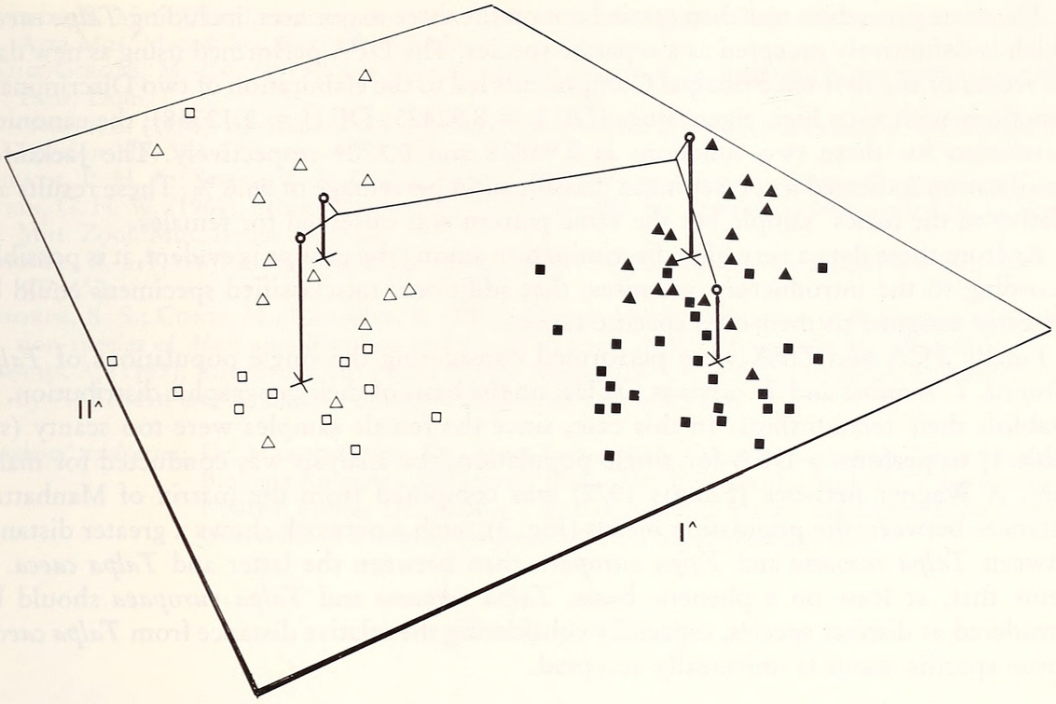

Fig. 2. A three-dimensional network computed from the matrix of Manhattan distances between population means is superimposed to the canonical bivariate plot which represents the distribution of four *europaea/romana* populations. Vertical axis is the 3rd canonical variate. These results are referred to the analysis performed on one sex (males). A similar pattern was obtained for females. △ *Talpa romana* from terra typica; □ *Talpa romana* from southern Italy; ▲ *Talpa europaea* from Piedmont; ■ *Talpa europaea* from Ravenna

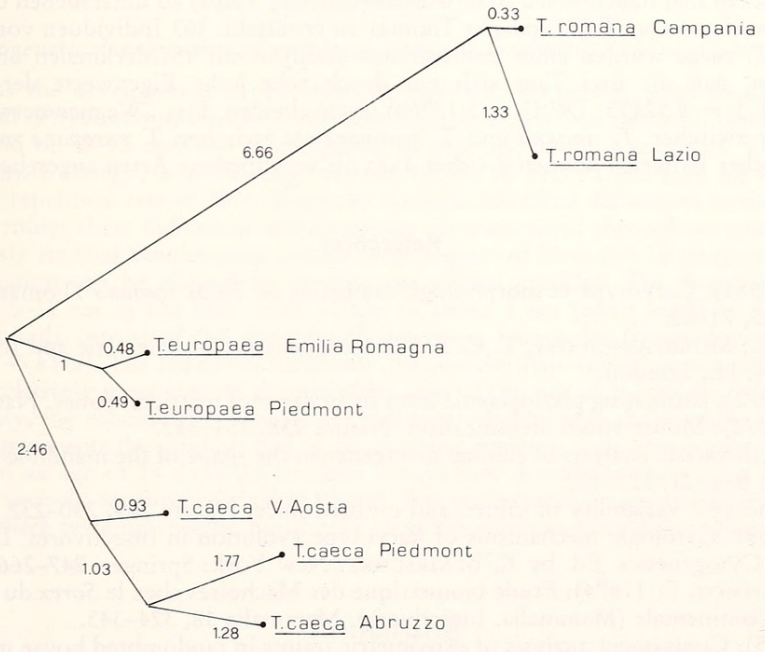

Fig. 3. A Wagner network computed from matrix of Manhattan distances between populations means of the 7 populations of *Talpa romana, T. europaea* and *T. caeca* (males only). Numbers refer to the Manhattan distances

The same procedure was then carried out on the three major taxa, including *Talpa caeca*, which is definitively accepted as a separate species. The DFA performed using as new data the scores of the first ten Principal Components led to the elaboration of two Discriminant Functions with very high eigenvalues (DF I = 8.92425; DF II = 3.12768); the canonical correlation for these two functions is 0.94828 and 0.8704 respectively. The Jacknifed classification indicated a correct mean classification percentage of 96.6 %. These results are relative to the males' sample but the same pattern was observed for females.

As from these data a very high discrimination among the groups is evident, it is possible, according to the introductory premises, that additional misclassified specimens could be correctly assigned to their own specific taxon.

Finally PCA and DFA were performed considering the single populations of *Talpa europea*, *T. romana* and *T. caeca* as OTUs, on the basis of their geographic distribution, to establish their relationships. In this case, since the female samples were too scanty (see Table 1) to perform a DFA for single population, the analysis was conducted for males only. A Wagner network (Farris 1972) was computed from the matrix of Manhattan distances between the population means (Fig. 3); such a network shows a greater distance between *Talpa romana* and *Talpa europaea* than between the latter and *Talpa caeca*. It seems that, at least on a phenetic basis, *Talpa romana* and *Talpa europaea* should be considered as distinct species, especially considering the relative distance from *Talpa caeca*, whose specific status is universally accepted.

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Zusammenfassung

Multivariate Analyse von Knochenmaßen italienischer Maulwürfe (Gattung Talpa)

Durchgeführt wurde eine morphometrische Studie an Knochen (Mandibeln), um die taxonomische Beziehung zwischen den italienischen Maulwürfen (Gattung *Talpa*) zu untersuchen und speziell, um den spezifischen Status von *Talpa romana* Thomas zu ermitteln. 163 Individuen von *T. romana*, *T. europaea* und *T. caeca* wurden einer multivariaten Analyse mit 15 Merkmalen unterworfen. Die Resultate zeigen, daß die drei Taxa sich gut durch sehr hohe Eigenwerte der Diskriminanz-Funktionen (DF I = 8.92425; DF II = 3.12768) unterscheiden. Das „Wagner-network" zeigt eine größere Distanz zwischen *T. romana* und *T. europaea* als zwischen *T. europaea* and *T. caeca*. Auf Grund phänetischer Kriterien können die drei Taxa als verschiedene Arten angesehen werden.

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Die ontogenetische Entwicklung der Vokalisation bei *Phyllostomus discolor* (Chiroptera)

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Abstract

Ontogenetic development of vocalization in Phyllostomus discolor (Chiroptera)

Investigated was the development of the isolation calls and the echolocation sounds in the Lesser Spear-Nosed-Bat *(Phyllostomus discolor)*. The isolation call occurs from birth till about 45 days of age. It has a duration of 40–75 ms, and is composed of 4–6 undulating harmonics. The fundamental, containing the main energy, is undulating between 10 and 28 kHz. These calls are emitted in series with a maximal repetition rate of 10/s. There are marked individual differences in time structure and frequency patterning; these individual characteristics are maintained throughout ontogenesis.

Spontaneously emitted echolocation sounds were registered from day 10 on (in younger bats this type of vocalization can be elicited by moving the animal quickly). The duration of the sounds decreases from 5–12 ms in the first week of life to about 1 ms (adult level) in the fourth week. Echolocation sounds consist of 5–6 downwards sweeping harmonics (frequency range of the 3rd harmonic 70 to 45 kHz). The 3rd or 4th harmonic contains the main energy; in younger bats the lower harmonics are relatively more intense than in older ones. At an age of 5–6 weeks, when the bats gain their flight ability, the echolocation sounds are indistinguishable from the sounds of adults.

In choice experiments the mothers had to discriminate between their own young one and another baby bat. Up to an age of 14 days the mothers always flew directly to their own, calling offspring (older juveniles actively approached their mothers). The young ones are apparently identified by their isolation calls; there were no specific social calls from the mothers during the reunion.

Einleitung

Die Vokalisation erfüllt bei den Mikrochiropteren zwei Funktionen: zum einen besitzen Fledermäuse spezielle Ortungslaute, die der Orientierung dienen, zum anderen finden sich

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